1. Purpose

The goal of this technical note is to explain one typical HI-1 straylight ghost that may be present in in-flight HI-1 images when a bright object is very close of the camera field of view (FOV) or even in the FOV.

2. HI-1 typical ghosts

Next HI-1 images show typical ring patterns (primary and secondary) associated to bright objects close to the FOV border, at the border and in the corners of the FOV. The primary ghost is relatively bright but the secondary ones are much fainter (quasi not visible in case of bright object in the FOV).

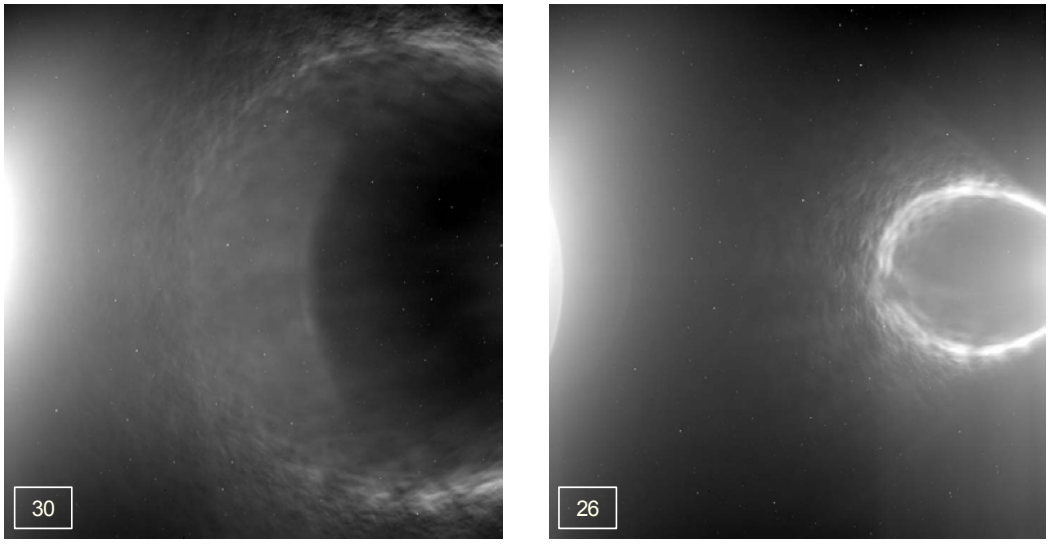

Figure 1: Typical HI-1 ghost pattern for bright object close to the FOV border (Earth just before entering the HI-1B FOV, for Sun-S/C-Earth respective angles of 30 and 26-arcdeg)

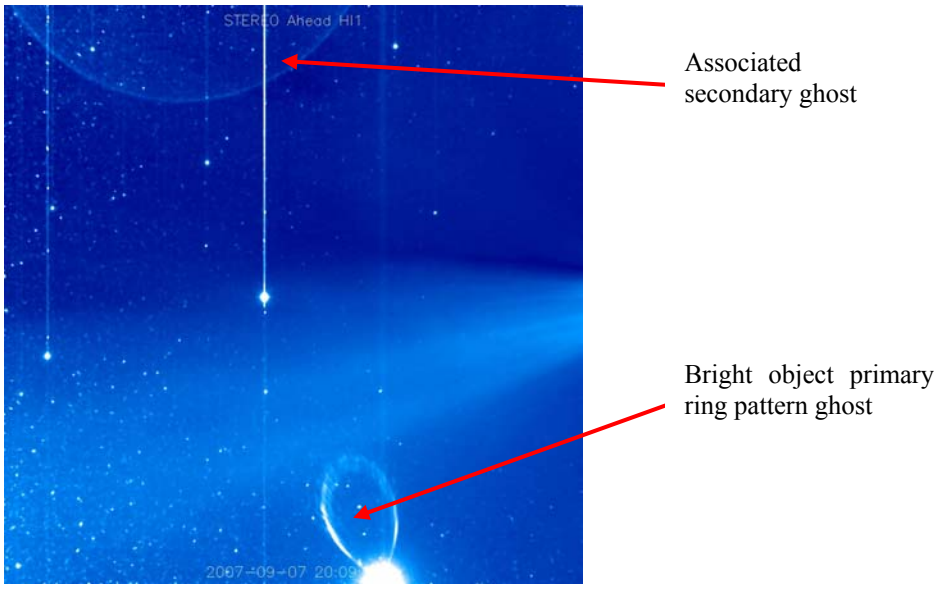

Figure 2: Typical HI-1 ghost pattern for bright object on the FOV border

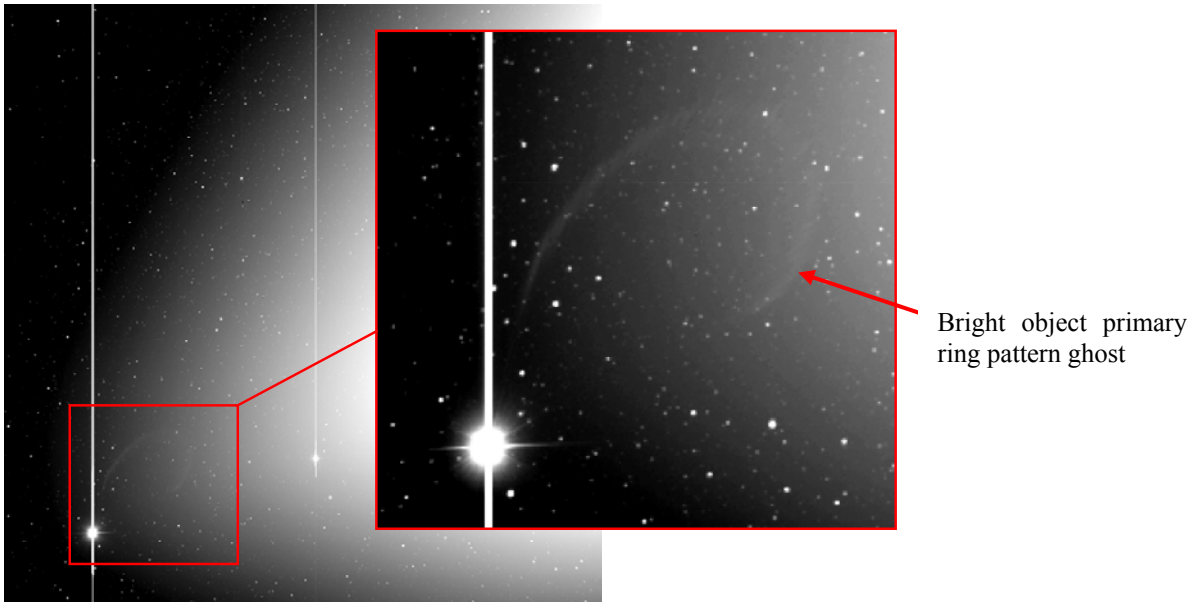

Figure 3: Typical HI-1 ghost pattern for bright object in the FOV

3. Ghosts origin

3.1. Bright object out of FOV

Ray-tracing model of the HI-1 camera optical system shows that the primary straylight ring pattern of a bright object, located outside the FOV, is produced by a reflection on the last two retainers of the HI-1 lens barrel. The further out of the FOV the larger the ring pattern and the less bright it will be.

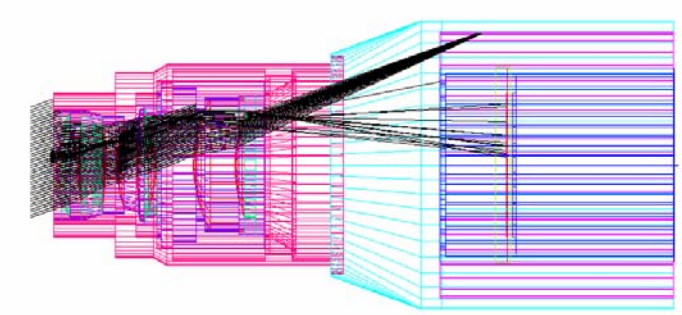

Figure 4: Ray tracing for a light source located at border of the HI-1 FOV

This effect is present wherever the bright source is located around the FOV, as the lens barrel is symmetric, but more pronounced when the bright source is around the corners of the detector.

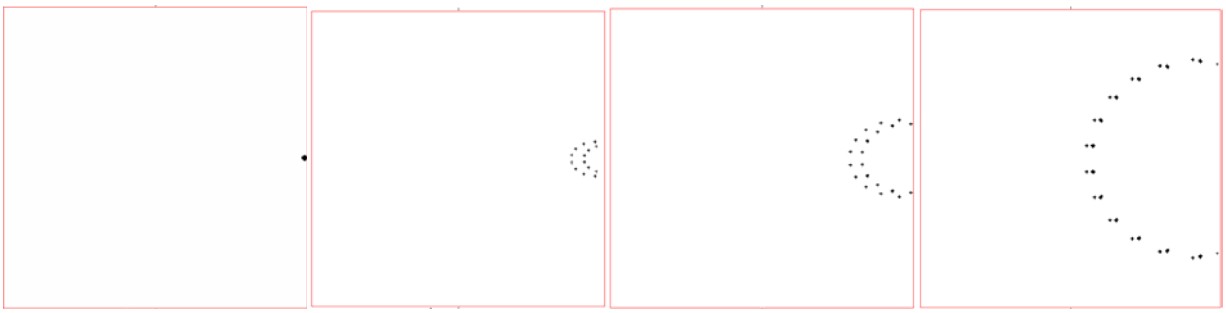

Figure 5: Ray-tracing results for bright source located at 0 / +3 / +7 / +15 arcdeg from border of the HI-1 FOV

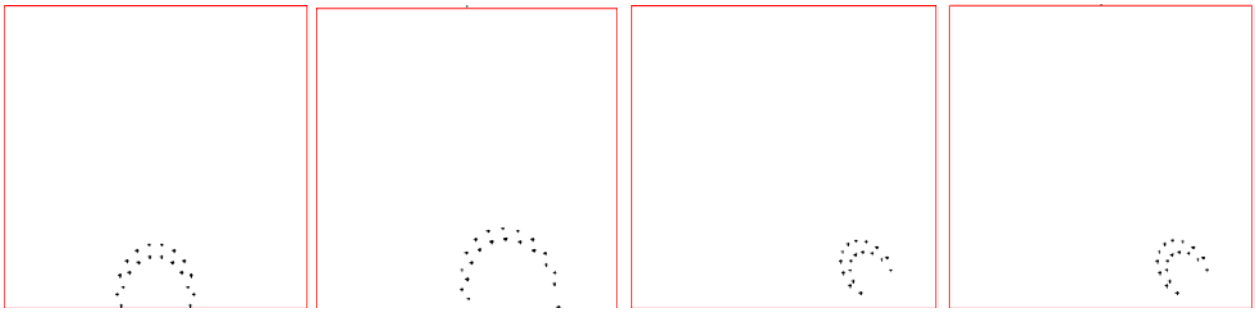

Figure 6: Ray-tracing results for bright source located at various location at 3-arcdeg out of the HI-1 FOV

The secondary ghost is due to reflections of primary ghost onto the CCD and last lens retainers and surrounding elements. It is therefore much less bright than primary

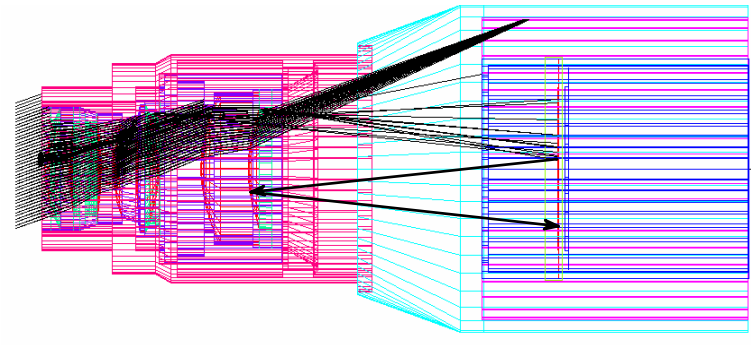

Figure 7: Secondary ghost origin

Next image is a HI-1B calibration result obtained with a collimated bright source located at 0.15-arcdeg out of the FOV (i.e. a source at 3.5-arcdeg from sun centre direction), where the primary and the secondary ghosts are clearly visible.

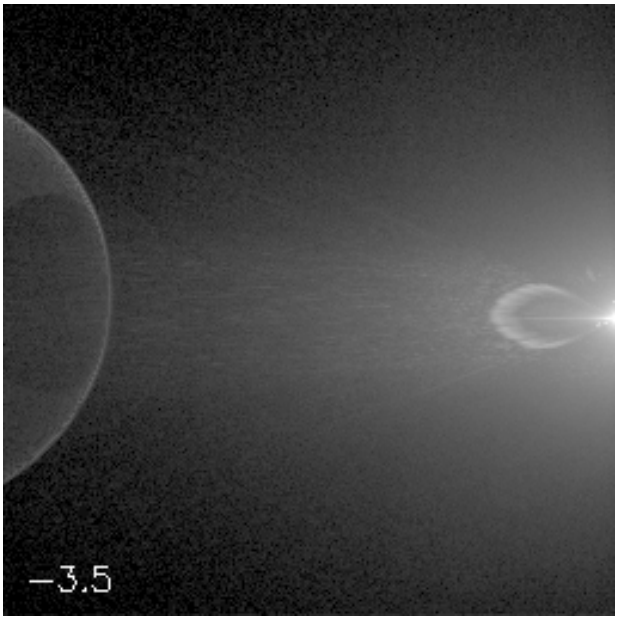

Figure 8: HI-1B calibration image where the collimator spot is at the border of the FOV

3.2. Bright object in the FOV

In case of bright object in the FOV, its rays should normally directly go to the CCD without interference with inside the lens barrel. However, ray-tracing shows that the retainer of second lens produces ghosts in the four detector corners.

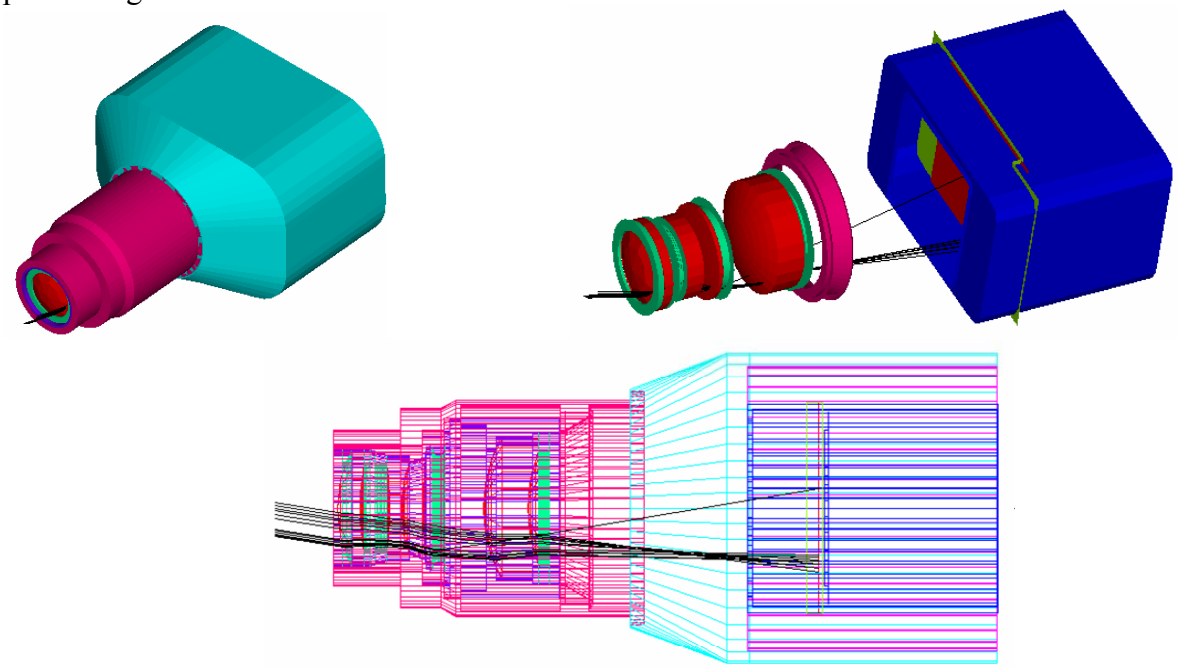

Figure 9: Ray tracing for a light source in the HI-1 FOV with incident angle focusing on a detector corner

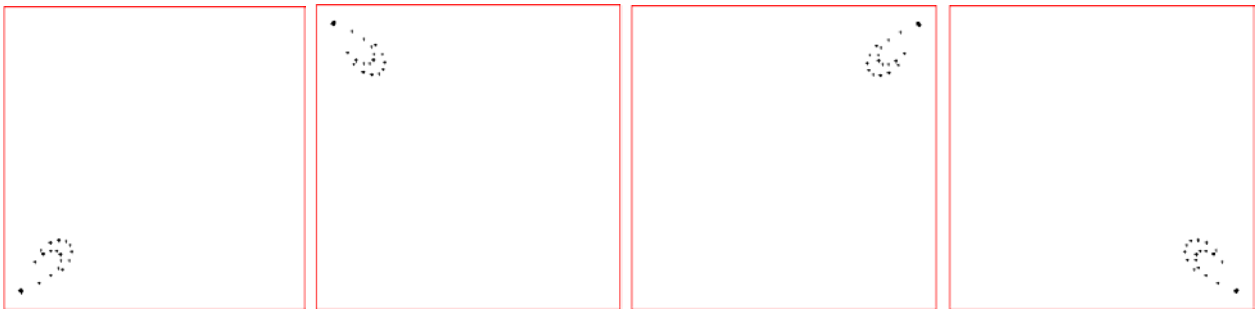

Figure 10: Ray-tracing results for a bright source located in the four corners of the FOV at 9 arcdeg from the HI-1 FOV centre

The original HI optical design has indeed been optimised for circular FOV, not for the area in the corners of the square detector. As shown on next figure, the ring pattern indeed reduces when the spot leaves the corner.

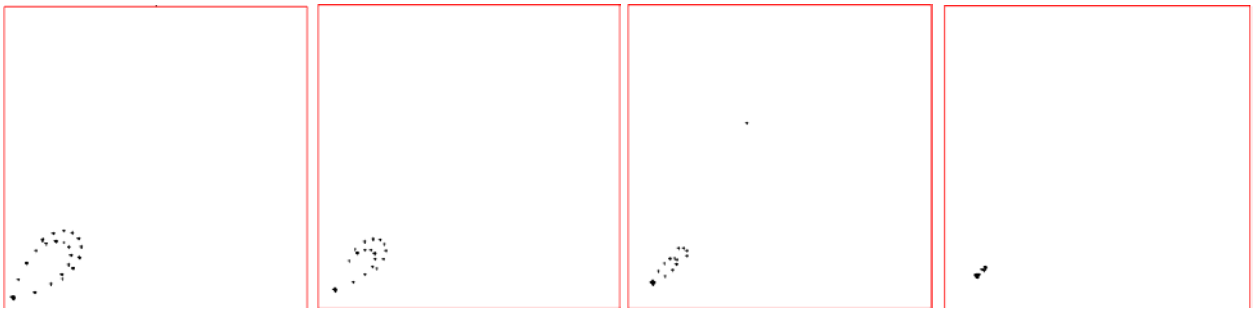

Figure 11: Ray-tracing results for a bright source located in corner of the FOV at 9.5 / 9 / 8.5 / 8 arcdeg from HI-1 FOV centre

Secondary ghosts are also present in ray-tracing results but much fainter and thus requiring high number of rays to be visible. Furthermore, internal elements coating and exact shape of the lens barrel are critical for secondary ghosts computation and a more accurate model would be necessary to improve these results.

4. Conclusion

The bright objects associated ring pattern observed in the HI-1 images are well identified and ray-tracing modelled ghosts produced by internal reflection in the camera lens barrel by retainers.

More generally large diffuse pattern that can be observed in the HI cameras are ghosts that are produced by internal reflections inside the lens barrels, when bright objects are in the FOV or close to the FOV border.